Microwave Backhaul for Microcellular Architectures

DragonWave

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If there was ever any debate regarding the end user appetite for wireless bandwidth, that issue has surely been put to rest. The kind of monthly data consumption that would have been associated with a bandwidth hungry wireline user only two years ago now fits the profile of an average user on several large wireless networks. In fact, data usage per subscriber on fixed and mobile wireless networks is now in many cases exceeding that of wireline broadband connections, with no signs of slowing down. Figure 1 provides data usage figures for several large wireless networks.

Service providers offering no-cap mobile plans are seeing the true appetite for mobile bandwidth.

Data Usage on Next Generation Wireless Networks

Operator	Country	Average Monthly Data Usage per Subscriber
Yota	Russia	12.7 GB
Packet One Networks	Malaysia	7.9 GB
Comstar	Russia	7.2 GB
Clearwire	US	7 GB
Tatung	Taiwan	7 GB
Enforta	Russia	3 GB
SK Telecom	Korea	2 GB

Figure 1 – Source: Maravedis, 2010

Operators have responded in a variety of ways including adding additional capacity through costly spectrum acquisitions – when it is available – or by imposing usage caps. Generally speaking, these are not long term solutions as they will either become prohibitively costly to sustain or greatly restrict users, leading to unhappy customers and higher churn. Upgrading to higher capacity 3G and 4G networks will significantly improve access capacity, but even this will not provide sufficient throughput for media rich applications in high tele-density areas.

Compounding this challenge is the unpredictable nature of future demand. A massive amount of activity in the consumer electronics space is resulting in the introduction of many innovative network enabled devices from a range of new and existing manufacturers. Service providers have consistently underestimated the impact of these devices; the iPhone being a prime example. While smartphones currently account for the majority of new mobile demand, a significant amount of future demand will come from other currently unconnected “things”. Video cameras, gaming consoles, automobiles and machine-to-machine communications are all examples of additional sources of traffic on mobile networks.

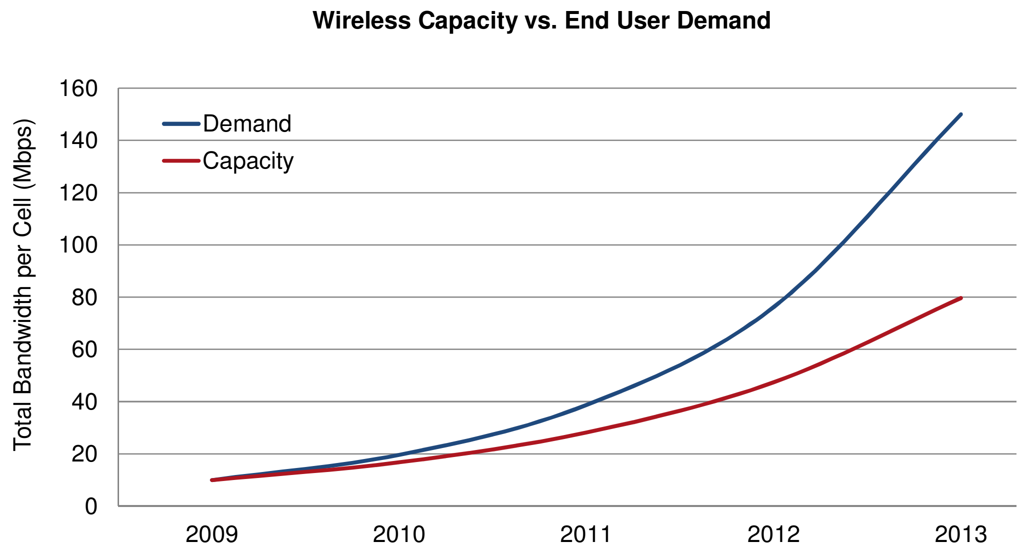

Figure 2 – Source: Cisco, Infonetics, 2009

Despite the advances in mobile networks there is a growing gap between end user demand and access bandwidth.

For many operators, the solution to this significant challenge will be the use of microcellular underlay networks. The smaller cells used in these deployments operate below the clutter level in order to improve coverage and offload traffic from the over-burdened macrocellular network. Not only does this architecture provide the scale for future demand, it also provides several important benefits in terms of coverage and spectral efficiency

While microcellular architectures hold a lot of promise, they also present a set of unique challenges for operators. This paper will provide an overview of the benefits and drivers for microcellular architectures, followed by an examination of the deployment considerations and challenges that this alternative solution presents. Finally, we will look at backhaul alternatives and present the requirements for microwave-based microcell backhaul solutions.

MICROCELLULAR NETWORKS: OVERVIEW

Microcellular networks are an underlay to the macrocellular layer. These cells are typically less than 1 KM in size and are deployed at street level, on street light poles, the sides of buildings or other suitable structures.

Existing microcell deployments typically consist of a micro-base station with some kind of wired backhaul. Looking forward, microcells are evolving towards fully integrated units containing a micro-base station, battery backup, backhaul components and in some cases switching – all within a small pole-mounted enclosure optimized for urban environments.

Aggregate microcell capacity far exceeds macrocell capacity while using existing spectrum allocations

Macrocellular Coverage with Microcellular Underlay Network

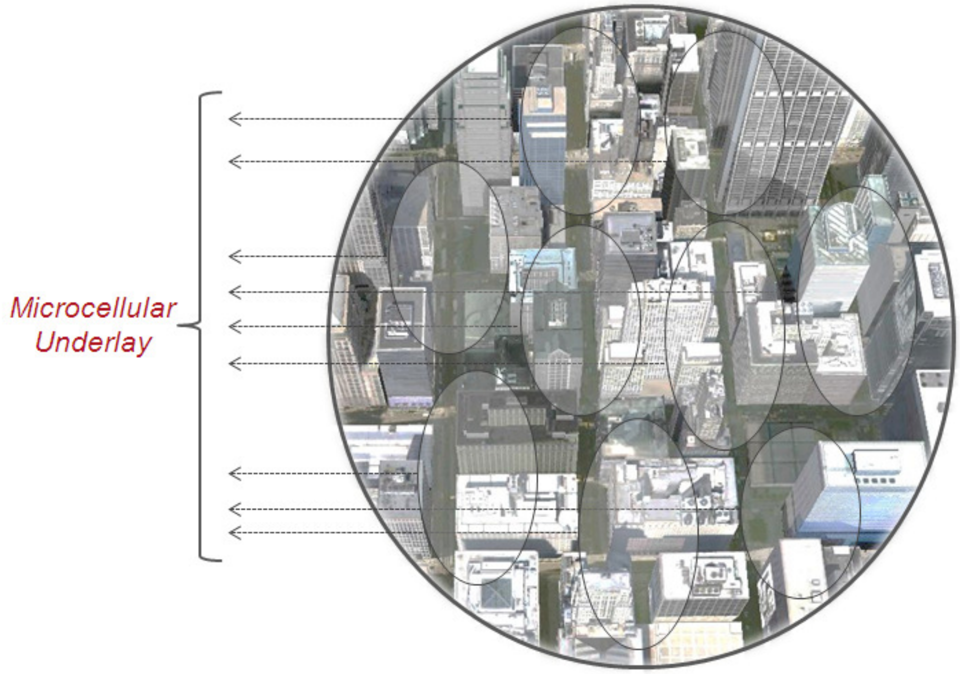

Figure 3

Distributed Antenna Systems (DAS) offer another approach to expanding coverage. With these systems, transmit power is split among several antenna elements, providing coverage over the same area as a single antenna system but at a reduced power level. While DAS systems improve coverage and make more efficient use of spectrum, they generally rely on centralized base station processing and thus do not deliver the equivalent increase in capacity seen in microcellular networks consisting of distributed base stations. In addition, DAS generally require RF signals to be converted and distributed over fiber and are therefore most commonly installed indoors where fiber is most readily available.

MICROCELLULAR DRIVERS

The most important drivers for microcellular network deployments are:

Capacity

As new types of network enabled devices come online and service providers begin to offer users single mobile data plans for multiple connected devices (iPhone + iPad) demand will greatly outstrip capacity.

Microcellular architectures offer a combination of better coverage and more base stations which results in a dramatic increase in network capacity; area previously covered by a single macrocell can see an order of magnitude increase in capacity with the addition of a microcellular layer.

In Building Coverage

By deploying base stations at street level (below the clutter level), microcellular networks offer much greater in-building penetration at lower transmit powers. This is particularly relevant to operators who are using higher-frequency access spectrum, such as 2.5 GHz and above; the lower propagation characteristics of these higher frequencies mean that in-building penetration would suffer significantly in traditional macrocellular architectures.

Spectral Efficiency / Re-Use

While some spectral efficiency gains are achieved with 4G networks and the use of MIMO technology, the majority of bandwidth increases are due to the larger channel sizes defined by these new standards. For example – HSPA is limited to 5 MHz carriers whereas LTE has defined channel bandwidths of up to 20 MHz and LTE advanced defines channel bandwidths of up to 100 MHz. A recent study by Rysavy Research projects that service providers will need over 200 MHz of spectrum in order to meet the bandwidth requirements of their users in 2016. With most operators holding between 50 and 100 MHz of spectrum, there will clearly be a shortfall based on current architectures.

Microcelluar networks present a compelling solution to this spectrum shortfall. Smaller cells allow for a large reduction in transmit power, enabling operators to re-use RAN spectrum within the microcellular network layer. In addition, for those deployments using microwave backhaul, operators have the ability to reuse the same backhaul spectrum for the higher elevation macrocells and the street level microcells – potentially leading to significant licensing savings.

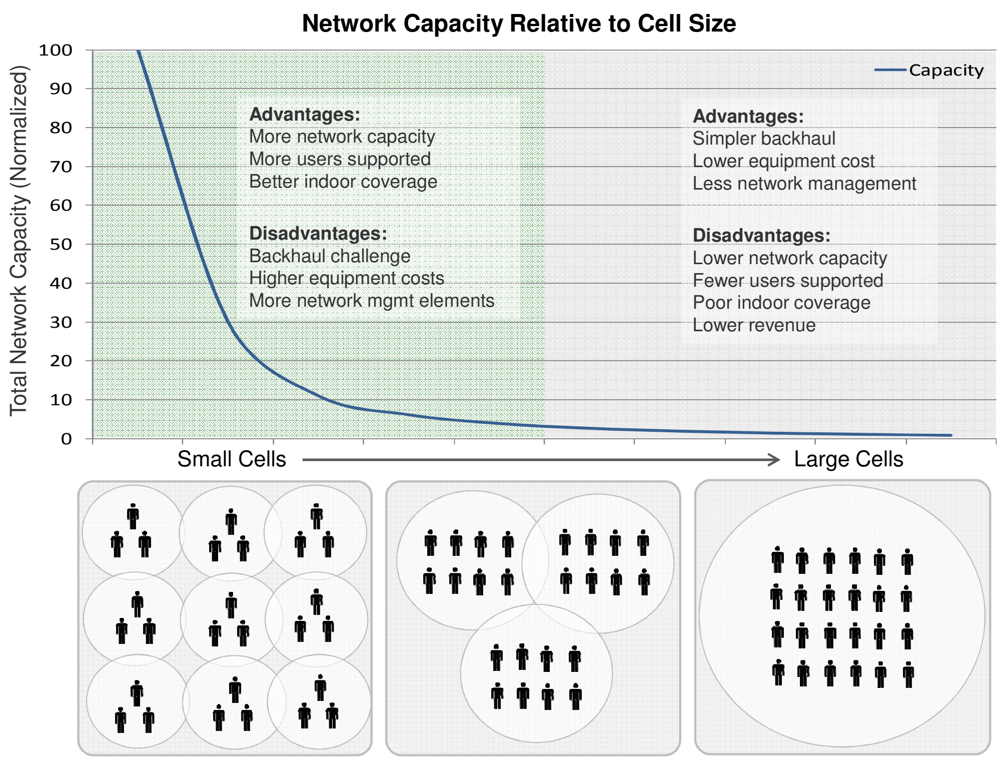

Figure 3: Cell size, capacity and users per cell.

MICROCELLULAR NETWORK DEPLOYMENT CONSIDERATIONS

Operators looking to deploy microcellular networks are faced with several unique challenges, requiring extensive market and network planning.

Installation Location

With microcellular networks operating at street level, existing towers cannot be utilized and operators must establish new installation locations on non-traditional structures – including street light poles, traffic light poles, bridges and the exterior walls of buildings. In order for the microcell units to operate in these locations, they must be fully integrated environmentally hardened outdoor units containing the base station, backhaul radio and modem (in the case of microwave), battery backup, environmental alarms, and in many cases local switching capabilities.

City Zoning Requirements

The placement and high visibility of the microcell units mean that operators must comply with a range of city zoning requirements. These generally dictate that street light pole-mounted equipment must be within a single enclosure with strict space and weight requirements. In addition, aesthetics are an important element – the units must blend into the urban environment.

Installation must be rapid in order to minimize any disruption to city traffic and operations. Installation must then be manageable by a single individual without the use of heavy equipment. Alignment and field replacement must also be fast and simple.

Microcell backhaul solutions

One of the most important considerations is the microcell backhaul solution. The unique locations where microcell units are installed mean that operators need to have a flexible backhaul strategy. The primary microcell backhaul options include fiber, in-band wireless and microwave.

Given that most microcells are deployed in high tele-density urban areas, fiber would seem to be an obvious, future-proof choice. In reality, while fiber is typically abundant in urban regions, it is rarely present where microcell units are deployed; street light posts and the exterior walls of buildings rarely have fiber in place and running fiber to these locations presents significant challenges in terms of cost, time-to-deploy and city permits.

Another backhaul option is to the use of in-band wireless, where a portion of the access spectrum is used for backhaul traffic. The advantage here is the ability to leverage existing spectrum asset; the disadvantage is that such spectrum is extremely valuable and typically best reserved for delivering revenue generating services. In addition, combining access and backhaul functions within a Time Division Duplex (TDD) construct results in lower backhaul throughput and introduces delay, making it unsuitable for many real-time applications.

With the many constraints of alternative backhaul options, out-of-band wireless solutions often offer the most compelling option when it comes to microcellular backhaul.

MICROWAVE BACKHAUL FOR MICROCELLULAR

Microwave backhaul offers several benefits in microcellular architectures relative to alternative solutions. By using dedicated frequencies, operators can maximize the use of their high-value access spectrum to deploy new services and increase revenue. In areas where fiber is not present, microwave backhaul links can be established quickly and cost effectively, with complete integration of all radio, modem and antenna elements within the microcellular unit.

FREQUENCIES FOR MICROCELLULAR BACKHAUL

The unique requirements of microcellular networks generally lead to the use of non-traditional backhaul spectrum.

The importance of small microcell package sizes that are optimized for street light pole-mounting and comply with city zoning restrictions, demand small (typically sub-1 foot), high-gain antennas. This, coupled with the need for minimal interference, generally leads to licensed higher frequency use, as outlined in the table below.

Band	Licensed?	Notes*	Optimal for µCell BH?
<6 GHz	Mixed	Limited spectrum, TDD (delay), shared users, mixed PtMP and PtP	N
6-8 GHz	Y	60cm min antenna, difficult to license in dense metro	N
11 GHz	Y	60cm min antenna, difficult to license in dense metro	N
18 GHz	Y	30-60 cm min antenna	N
23 GHz	Y		Y
24 GHz UL	N	Short range, but interference risk	Y
24 DEMs	Y	Area license in US/Canada	Y
26 GHz	Y	PtP license in most European countries	Y
28 GHz	Y	Area license in US and some European countries	Y
32 GHz	Y	Area license in US, point to point in many European countries	Y
42GHz	Y	In some European countries	Y
60 GHz	N	Very short range	Y
70/80	Y (light)	30cm min antenna	N

As show above, sub-6 GHz frequencies are generally not well suited for microcellular backhaul. Unlicensed frequencies such as 5.8 GHz are subject to a large amount of street level interference, rendering this band unreliable for mobile backhaul applications. Other sub-6 GHz licensed frequencies use valuable access spectrum which is better used to deliver services. In addition, these solutions generally employ point-to-multipoint architectures with fewer redundancy options, resulting in lower availability than a ring or mesh solution. Lastly, these systems are subject to higher levels of self-interference, greatly impacting performance.

In the case of licensed backhaul frequencies below the 18 GHz range, there is are regulatory requirements for larger antenna sizes, making them unsuitable for microcell backhaul due to city zoning and wind loading restrictions.

KEY MICROWAVE REQUIREMENTS FOR MICROCELL BACKHAUL

Hardened outdoor solution with rapid deployment

Microwave backhaul solutions for microcellular networks must be hardened, all-outdoor units with radio, modem and power supply fully integrated into an urban-landscape-friendly microcell package. Advanced installation features including simple Receive Signal Level (RSL) readings are essential to ensuring rapid deployment.

Simple installation, management and scalability

These microwave systems should also offer simple remote scalability to several hundred Mbps capacities – particularly for aggregation links. Advanced radio features such as adaptive modulation and high modulations in all channel sizes are essential in meeting the requirements of next generation access networks.

IP-based

With the majority of microcell deployments expected to leverage 4G mobile technology, IP-based backhaul systems will offer the most attractive performance and economics for these networks.

Flexible architectures

Lastly, the nature of microcellular deployments, and the line of sight requirements of microwave, will demand flexibility in the backhaul network architecture. Links will either zigzag along streets, from street corner to street corner or they will connect back to a high point (such as the top of a building) in the network. Depending on pole availability and line of sight options, a combination of topologies will likely be required. These topologies will include hub and spoke, daisy chain, ring and mesh as shown in figure 4 below.

Site availability, city layout and capacity requirements will all influence the microcellular backhaul architecture

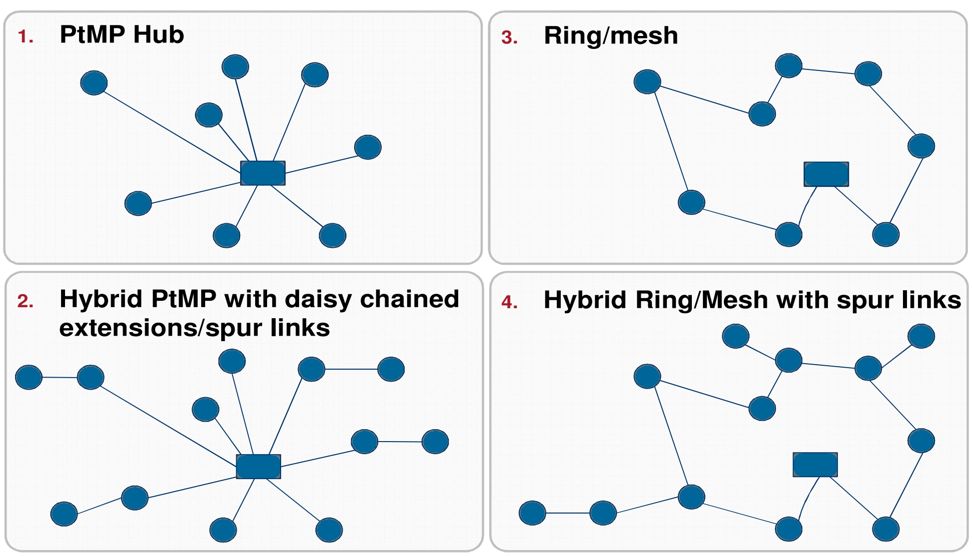

Figure 4: Network topologies

In these diagrams, the rectangle represents a high point backhaul node that is part of the microcellular layer and is also the exit point for the microcellular layer. Given that most of these architectures aggregate several links, backhaul capacity well beyond 100 Mbps would be required. In addition, ring/mesh switching capabability within the microcell would enable carrier grade availability.

CONCLUSION

Just as we have seen a trend towards distributed architectures in computing and content delivery, a similar shift is taking place in wireless networks. Microcellular networks will allow operators to provide better in-building coverage, maximize the use of their precious spectrum and scale their capacity to levels previously seen only on wired networks.

This nascent technology does however require careful planning to ensure optimal site selection and compliance with city zoning requirements. Furthermore, it is important for operators to adopt a flexible backhaul strategy to minimize capital and operational costs as well as deployment timelines. Due to the significant increase in equipment deployed, operational simplicity and sophisticated remote management are paramount to the ongoing operation of the system.

Looking beyond initial deployments which will be focused primarily on high tele-density urban areas, it is highly probable that suburban, rural and underdeveloped regions will also benefit from these solutions, allowing mobile service providers to deliver 10 Mbps and beyond to the home.

Regardless of where microcellular networks are deployed, operators will rely on a combination of technologies to solve their backhaul challenge and microwave will play a very important role in enabling the widespread build-out of these solutions.